Strut Braced Wings

A challenge or an opportunity?

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- Topics for this workshop
  – Challenges to minimise interference drag at the strut/wing interface
  – Flow Control for on- or off-design – the key question!

Some examples from the archives

Miles HDM-105

Hurel-Dubois HD.31

Waldo Waterman – NASA archive

Sugar Volt – with props

Piper Cub

Observations on ‘existing’ SBW configurations

- While there are numerous examples of operational aircraft with strut braced wings, what can we learn from the fact that they are seen to be;
  - Low speed aircraft
  - relatively small
  - Significantly outnumbered by simple cantilever configurations

- Given the need to balance between the advantages and disadvantages are there any clues as to which aspect of SBW configurations could unlock the potential
  - Do we design for on-design or off-design performance?
  - Do we focus on system simplicity?
  - Do we try to minimise the buckling loads on the strut?
  - Can we successfully manage the consequences of transonic flows and meet the Certification and Operational requirements?

- **This workshop is focused on the opportunity to integrate flow control to better manage the interference drag.**
  - This would be a significant advance and could not only unlock a key constraint of the SBW configuration but could also enable the Certification of a practical, high speed flow control application.

Strut Braced Wings: the opportunities

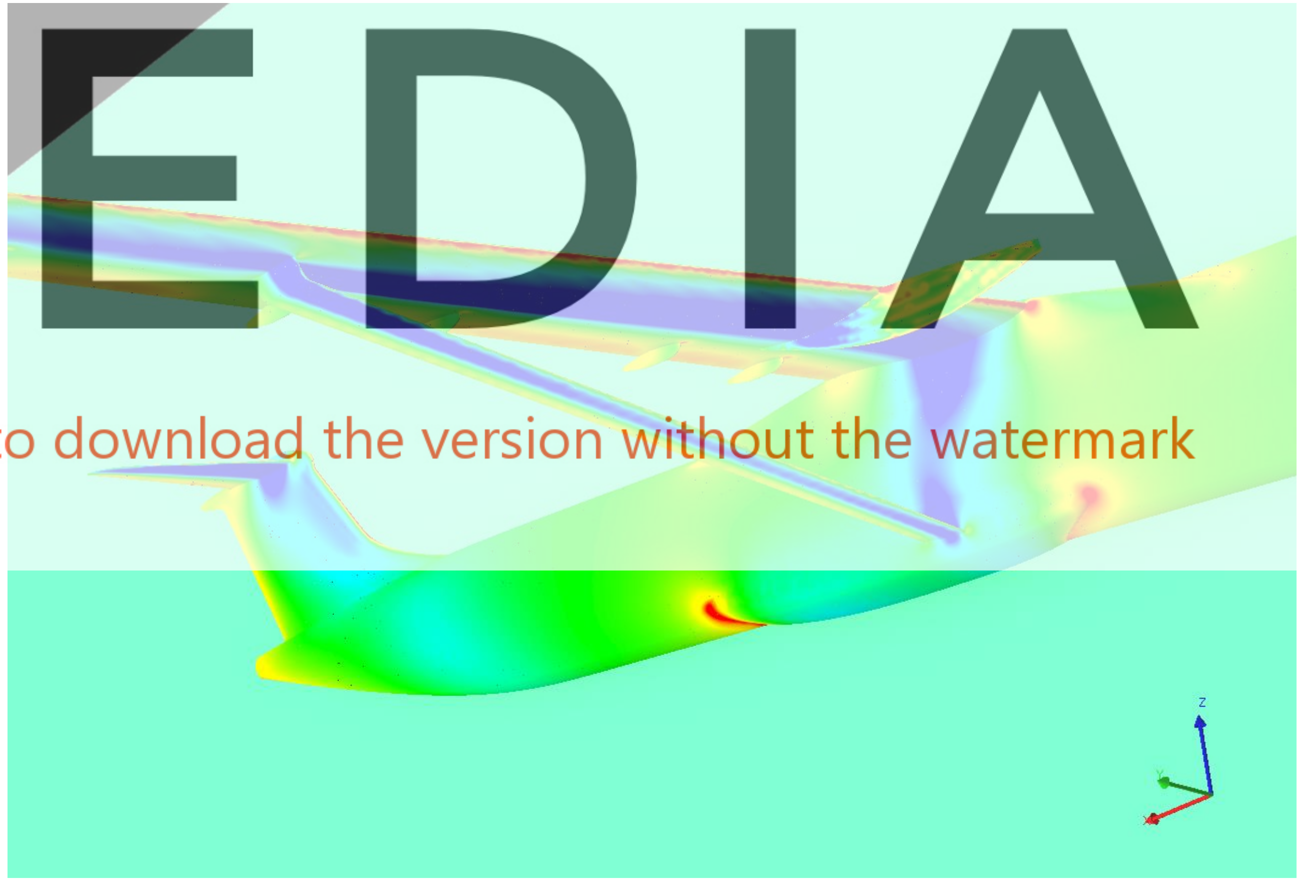
- ***High span***
  - *Drag force is proportional to span loading and so, for a given weight, more span is beneficial*

- ***Reduced weight for a given area***
  - *The ability to geometrically expand the load paths offers the possibility of reduced wing weight for a given span*

- ***Simplicity of high lift systems***
  - ***The aerodynamic efficiency of the higher span offers improved low speed performance and therefore requires simpler trailing edge systems***

Strut Braced Wings - the challenges

- *On design examples*
  - *Interference drag – the topic for this workshop*
  - *Handling qualities e.g. roll and yaw control*
  - *Gust response*
  - ***Aeroelastics***
  - ***Operation in icing conditions***



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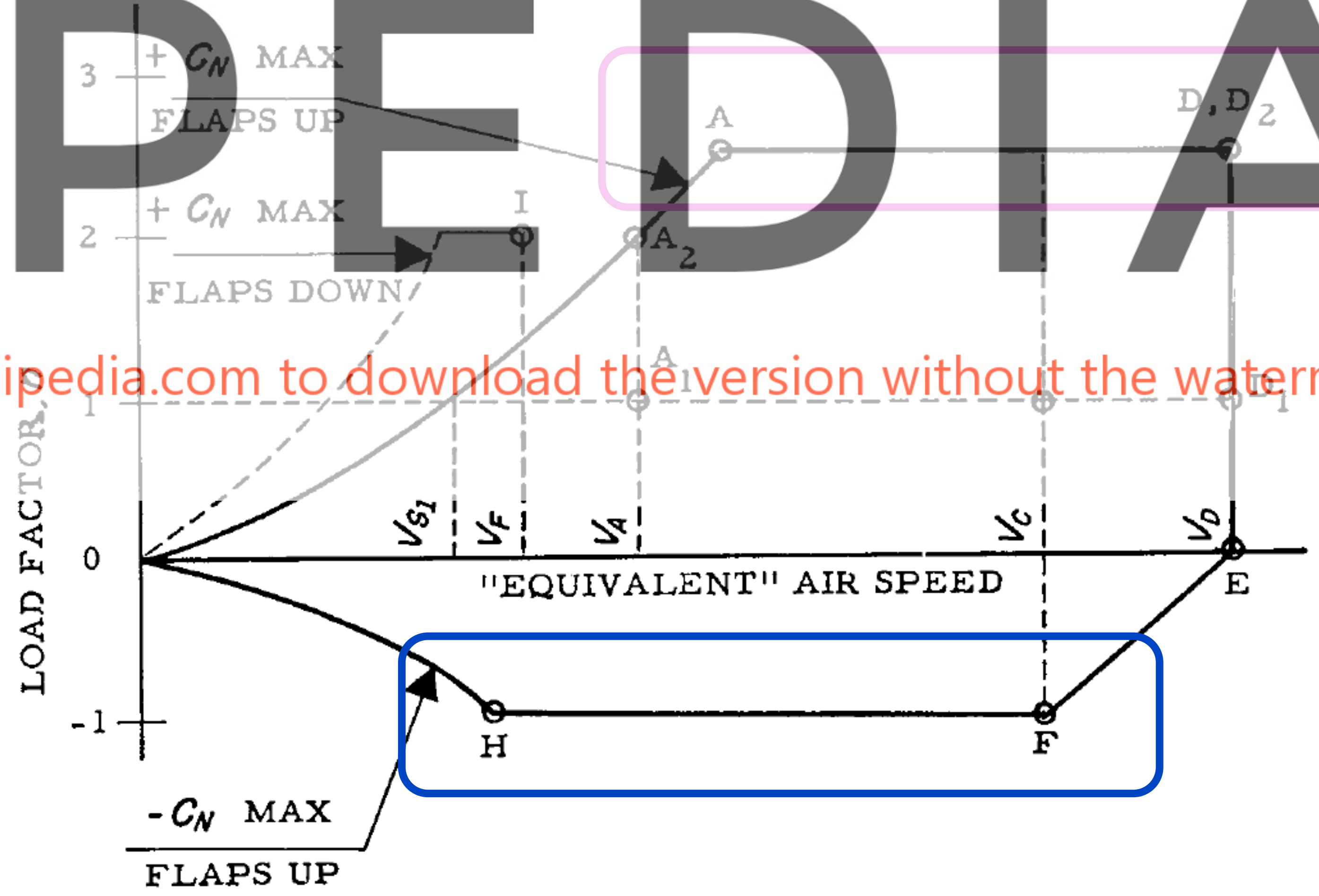
Strut Braced Wings - the challenges

- *Off design examples*
  - *Manoeuvre loads*
  - *-1g loads*
  - *Ground loads*



Strut Braced Wings - the challenges

- *Other factors that should be considered*
  - *Fuel system integration*
  - *Propulsion integration*
  - *Structural efficiency of wing box and landing gear integration*
  - *Gate limits*
  - *Speed flexibility*

Challenges associated with Airline Operations

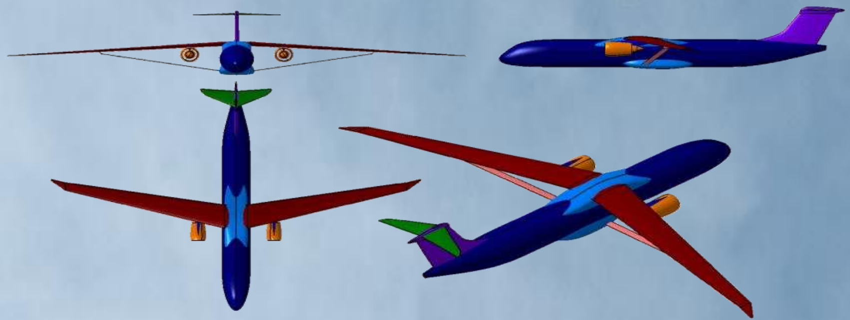
- Reliability
  - Can the additional systems operate successfully for 7+ years without affecting dispatch reliability
- Maintenance
  - Can the additional systems operate successfully with minimal (preferably no) cost of maintenance?
- Ground handling
  - Does the configuration impact any aspects of ground handling?

- Performance that cannot be cashed
  - If flow control is used, can it be monitored in a way that the aircraft knows the benefit it is achieving?
  - Do we need an associated health monitoring system?
  - Will it work when it is needed?
- Lack of speed flexibility
  - A degree of Mach flexibility is highly desirable and particularly so for an aircraft flying many sectors each day.
  - Can a SBW configuration with flow control offer that capability?

The PADRI Workshop

A Flow Control Design Challenge

Flow control as configuration enabler



This computational platform allows all the contributors to compare their respective results with deltas values with respect to the same reference and to show the benefit of the chosen flow control technology.

This simplified platform will help to:

→Allow testing and comparison of different drag reduction techniques

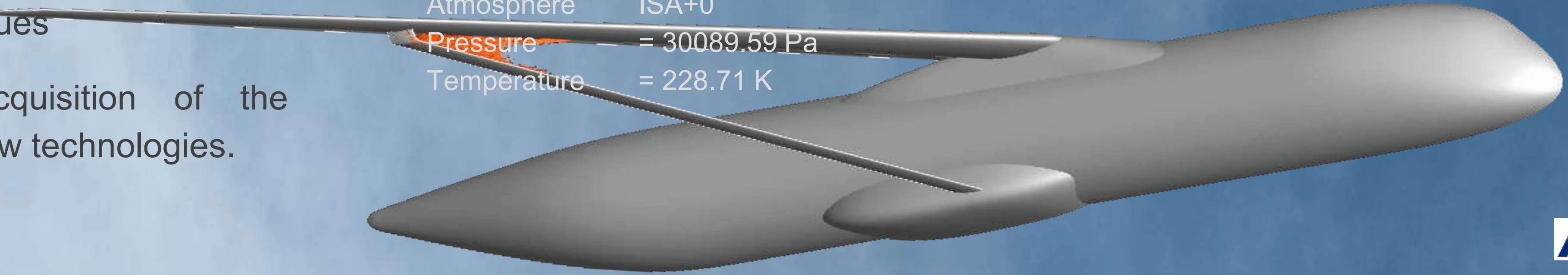
→Ease knowledge acquisition of the application of these new technologies.

Flow control design challenge

This test case has not been optimized for drag, but it reproduces, even at low velocity, a typical **shock wave** pattern in the region of a **junction strut-wing**.

The objective is to find candidate flow control technologies that can minimize shock wave and interference drag in the strut-wing junction region in cruise condition.

Mach	= 0.72
Angle of attack	= 1º
Reynolds/length	$=7.1\cdot10^{6}m^{-1}$
Altitude	= 30000 ft
Atmosphere	ISA+0
Pressure	= 30089.59 Pa
Temperature	= 228.71 K



Targetting wave drag

The goal:

- Master the interference in a complex flow at wing-strut junction.
- Find the best technology to be applied in this situation
- Define the best setup of the flow control

Platform description:

- Constraints
- Objective functions
- Methodologies

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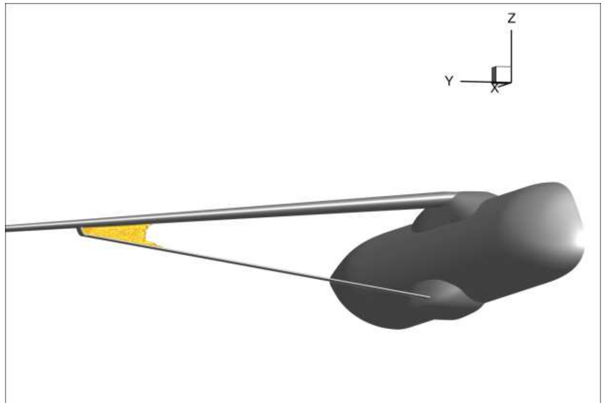
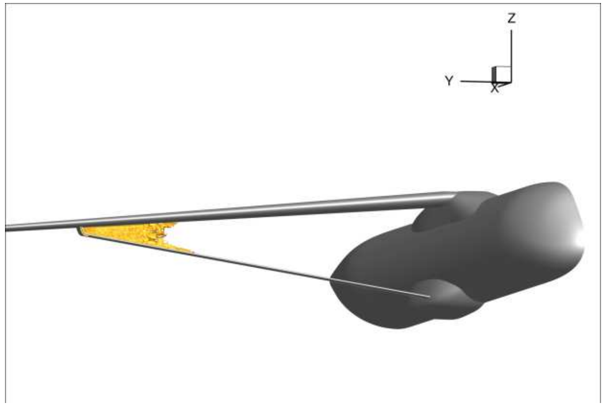
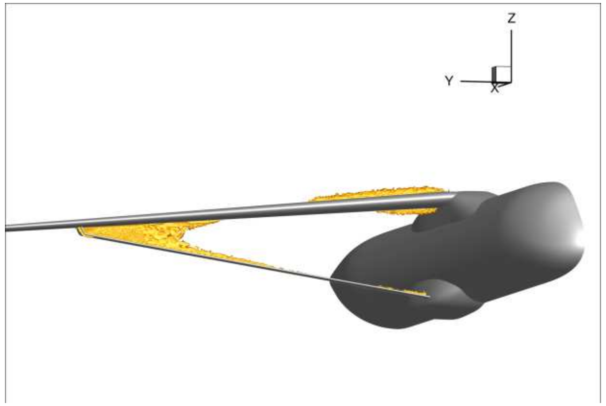
The development of interference drag with Mach number



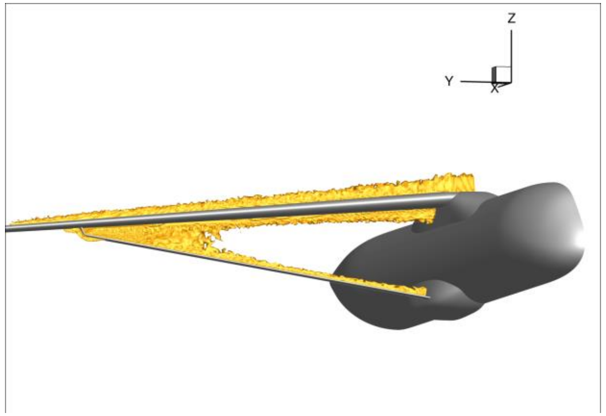
Mach 0.68 Alpha 1.0



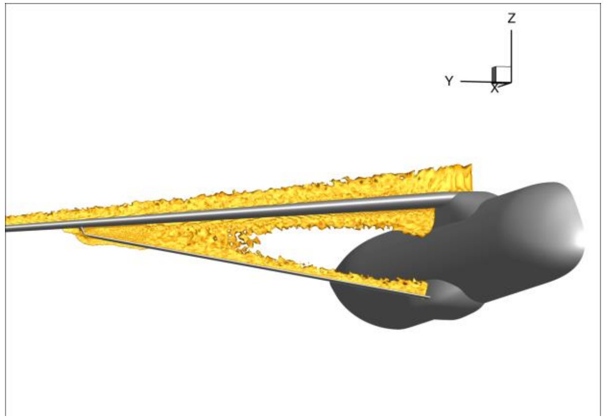
Mach 0.70 Alpha 1.0



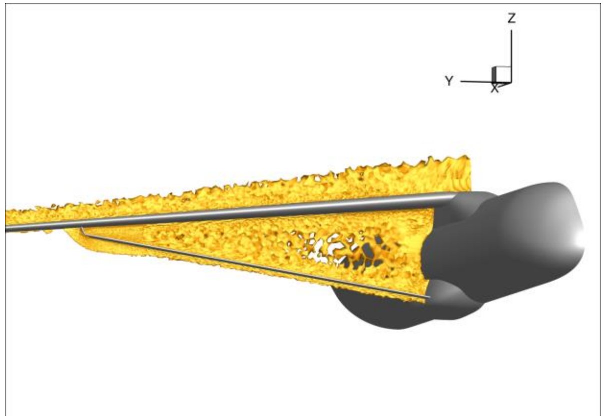
Mach 0.72 Alpha 1.0



Mach 0.74 Alpha 1.0



Mach 0.76 Alpha 1.0



Mach 0.78 Alpha 1.0

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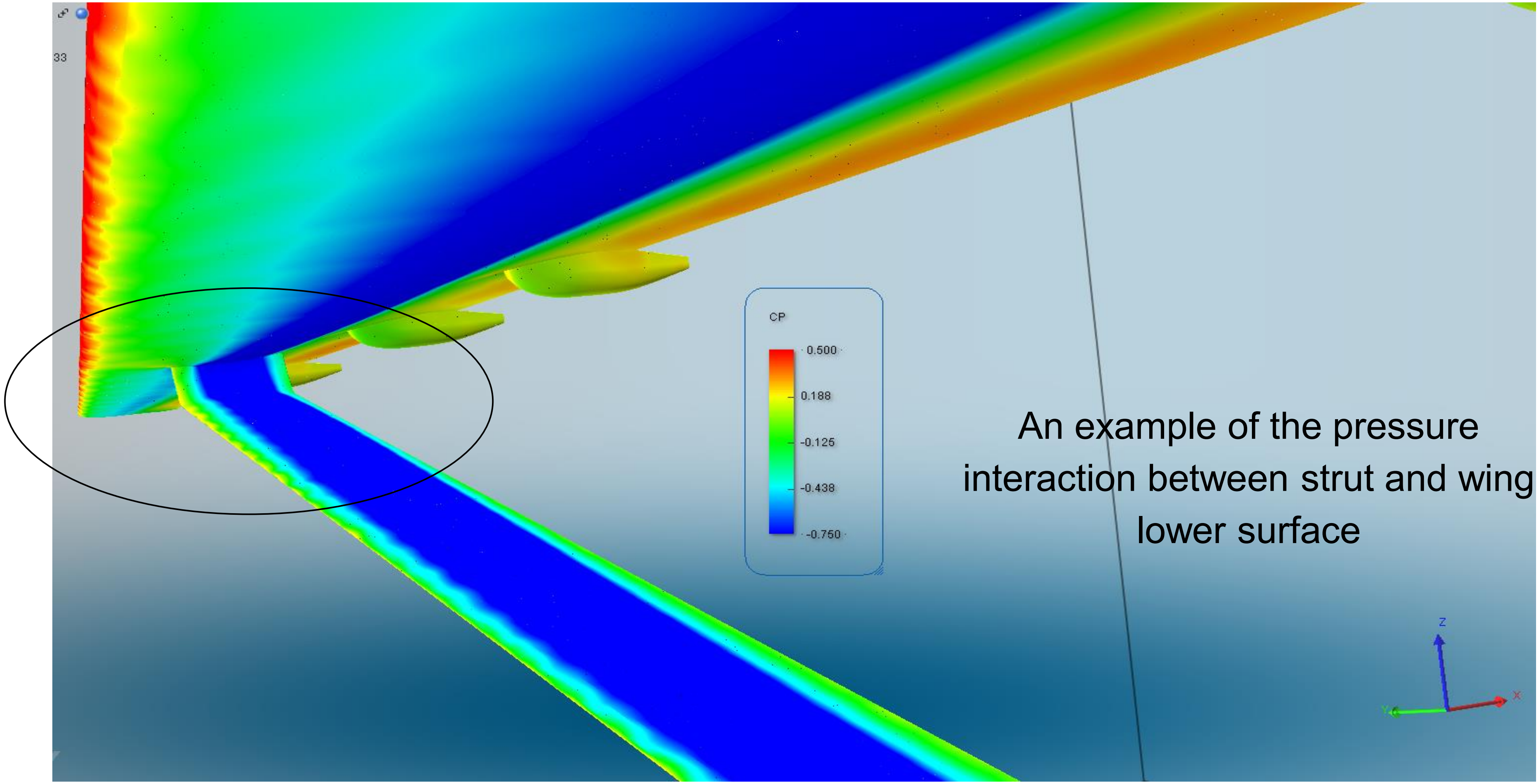
Novel technologies that could be of value to SBW configurations

- It should be assumed that, for economic reasons, it is required:
  - To operate at the maximum cruise speed possible - including transonic flows
  - To offer a significant improvement in Cash Operating Cost (COC) compared to existing aircraft.

- Therefore the following may be of relevance:
  - Shock control technologies to manage interference drag, flutter and buffet
  - Advanced sensing networks
  - Aeroelastic tailoring
  - Gust load alleviation
  - Folding wing tip concepts to meet gate limit restrictions
  - Laminar flow techniques

Do any of these technologies offer opportunities for synergistic groupings? Does the choice of GLA system, for example, influence the type of flow control for the management of interference drag?

The specific example of interference drag at strut/wing interface



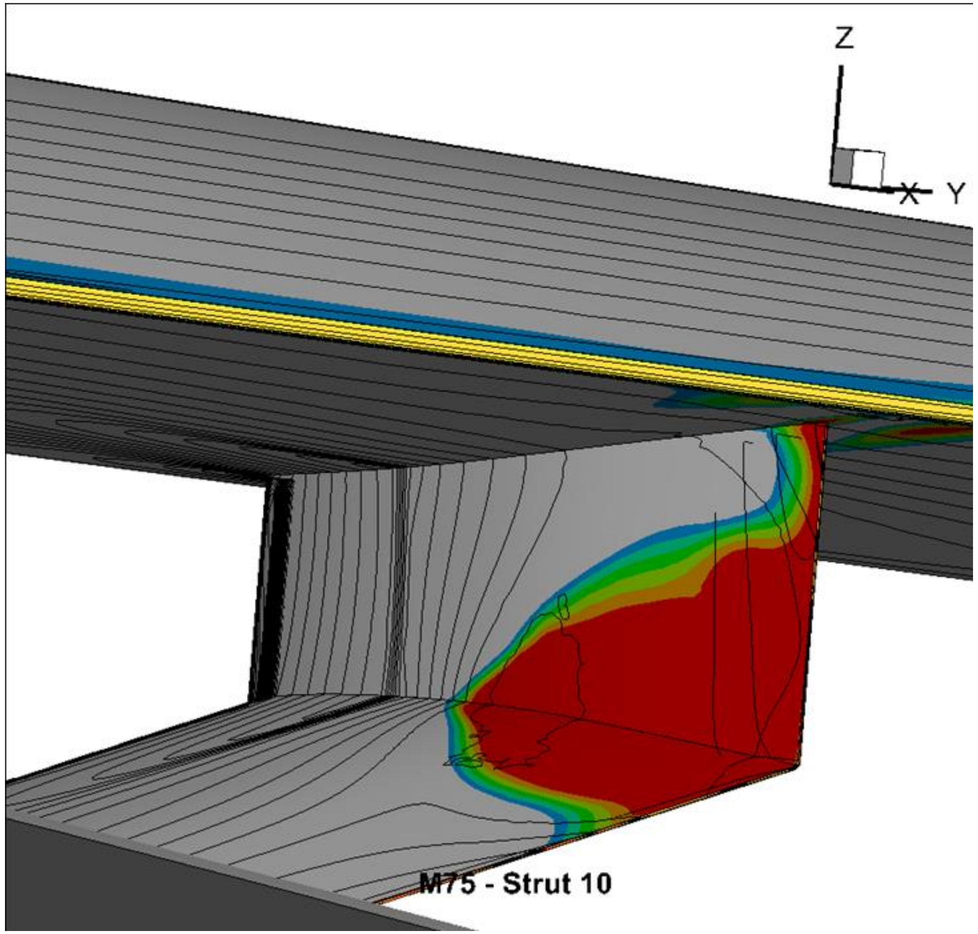
An example of the pressure interaction between strut and wing lower surface

Challenges to minimise interference drag at the strut/wing interface

- Range of operating conditions
  - On-design and off-design

- Rapid onset of shock strength as a function of the local geometry

- Consequences of a poorly conditioned shock
  - Flow separation
  - Dynamic loads
  - Acoustic tones
  - Asymmetric behaviour and undesirable HQ



Passive or active?

- **Passive flow control**
  - Highly desirable: no power requirement, no maintenance, low cost, reliable
  - But may be restricted in benefit
  - No significant challenges for Certification perceived at this time

- **Active flow control**
  - May give greater benefit over a wider range of operating conditions
  - But then requires monitoring, power, maintenance etc
  - New ground for Certification if it is part of the primary flight control system or if it impacts the safe operation of the aircraft
  - Probably less impact if it is only a performance enhancement but this may diminish the overall benefit

Independent of the chosen system it is vital that it is defined during the early phases of design and not included as an add-on.

Flow Control for on-design or off-design – the key question!

- For an on-design solution:
  - It will need to work for a long time
  - It should not penalise off-design loads or performance
  - It should require only enough power so as to enable a net benefit to the aircraft
  - It should be demonstrable that it is working
  - It needs to work for a variety of aircraft weights and operational conditions including the effects of flexibility

- For an Off-design solution:
  - It should not penalise the on-design performance
  - It needs to work when it is required and that may be infrequently.
  - It needs to be understood how it might impact dispatch reliability

The flow control approach will be dependent on the chosen scenario

Challenge for this workshop

- Propose a flow control solution to manage the interference drag for a strut braced wing configuration that:
  - *Works across a range of flight conditions without penalty*
  - *Requires no maintenance*
  - *Costs nothing*
  - *Weighs nothing*
  - *Works for the life of the aircraft*

Over to you!

Thank you